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DECLARATION

I, Dr. Wolfgang Döring, Patent Attorney, of Mörikestr. 18, 40474 Düsseldorf, Federal Republic of Germany, do hereby declare that I am conversant with the German and English languages and I certify that the following translation is to the best of my knowledge and belief a true and correct translation of the authentic text of PCT application PCT/DE02/02328.

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Automatic sun position follow-up means

The present invention is directed to an automatically functioning sun position follow-up means for solar modules.

It is known to guide solar modules (solar collectors, solar panels etc.) in response to the position of the sun in order to enable an optimum exposure to sunlight. Normally, it is desired to obtain a vertical impingement of the sunlight onto the plane of the solar module which assures the optimum energy yield. If this is not the case, i.e. if the sunrays impinge onto the plane of the solar module with a smaller angle or with a larger angle than 90°, the energy yield is lower.

Since, according to the time of the day, different angles of incidence of the sunrays are present the solar module has to follow the position of the sun. This can be carried out manually which, however, is troublesome and time consuming. However, already automatically functioning sun position follow-up means for solar modules are known according to which the position of the sun is detected by

means of a sensor, corresponding signals are generated in response thereto and are supplied to a control unit, and the control unit controls respective drive units for the solar module in response to these signals in order to move the solar modul into an optimum position with regard to the sun.

It is the object of the present invention to provide an automatically functioning sun position follow-up means for solar modules which is characterized by a compact and sturdy construction with small need of maintenance.

According to the invention this object is achieved by an automatically functioning sun position follow-up means for solar modules comprising

a base for mounting the means at a stationary or movable part, especially a vehicle;

a rotary plate rotationally supported on the base and driven by means of a rotary drive;

a pivot frame pivotally supported on the rotary plate and driven by means of a pivot drive and having supported thereat at least one solar module; and

an optosensor generating signals in response to the position of the sun and supplying the same to a control unit which controls the rotary drive and/or pivot drive;

wherein the pivot frame includes at least one member fixedly connected to the rotary plate and a pivot member pivotally supported at said one member and carrying the solar module, the pivot drive is supported in the end portion of the member which is fixedly connected to the rotary plate transversely with respect to the axis thereof and does not protrude beyond this member upwardly, and the pivot drive includes a motor, a reducing transmission and a transmission output shaft provided with a toothing and with which a sector gear connected to the pivot member of the pivot frame is in engagement.

With the inventive sun position follow-up means it is possible to turn one or a plurality of solar modules (solar collectors, solar panels) about a vertical axis and to pivot the same about a horizontal axis. By this, the solar module or the solar modules can be brought into a position in which the sunrays substantially vertically impinge onto the plane of the modules so that in this manner an optimum energy conversion (into electrical current) can be obtained. The movement of the solar module or of the solar modules takes place automatically in response to the position of the sun wherein an optosensor detects the position of the sun, generates corresponding signals and supplies the same to the control unit. The control unit controls the rotary drive and/or pivot drive which generate the necessary movements of the solar module or the solar modules about the vertical axis and/or the horizontal axis for the follow-up of the sun position.

The inventive sun position follow-up means can be fastened to a stationary or to a movable part. In an especially preferred manner it serves for the fastening to a vehicle, for instance a mobile home or a caravan, especially on the roof of the same. The solar module or the solar modules can take over the current supply of the mobile home or the caravan.

The inventive sun position follow-up means has a base for mounting to the stationary or movable part and a rotary plate rotatably supported on the base and driven by a rotary drive. A rotary movement of the rotary plate and thus of the solar module or of the solar modules about a vertical axis of rotation takes place by means of the rotary drive which is controlled by the control unit. A pivot frame is disposed on the rotary plate which pivot frame can be pivoted up and is brought into the corresponding pivot position by means of a pivot drive. The solar module or the solar modules are fastened to the pivot frame. The pivot frame can be moved from a position parallel with respect to the rotary plate (with a pivot angle of 0°) into a pivot-up position of about 90° and back again.

On principle, the pivot frame has a member fixedly connected to the rotary plate and a pivot member pivotally supported at this member and carrying the solar module or the solar modules. It is essential that the pivot drive, which is disposed in the end portion of the member fixedly connected to the rotary plate, i.e. in the end portion in which the pivot bearing between the two members is

provided, substantially does not protrude beyond the upper side of the member fixedly connected to the rotary plate in order to make it possible that solar modules can be arranged along the whole length of the members and, on the whole, a low height of construction is achieved according to which no mechanical parts protrude upwardly in the pivot-down condition. By this, the whole area above the members can be used for the arrangement of solar modules, and low moments occur when pivoting up. Furthermore, the wind forces attacking the means are reduced which is especially of importance for the arrangement of the sun position follow-up means on the roof of a vehicle.

This desired compact construction is especially achieved by the design and arrangement of the pivot drive. The pivot drive is supported at the member fixedly connected to the rotary plate transversely with respect to the axis (longitudinal axis) thereof and includes a motor, a reducing transmission and a transmission output shaft provided with a toothing wherein a sector gear connected to the pivot member of the pivot frame engages the output shaft. The sector gear is designed and arranged in such a manner that it does not protrude beyond the pivot member upwardly. This would be the case with a normally designed gear with complete circle.

When the motor (electrical motor) of the pivot drive is controlled the shaft thereof is rotated. By the used transmission a gear reduction is achieved, preferably with a ratio of about 1:180. Accordingly, the output shaft of the transmission rotates substantially more slowly than the

motor shaft and pivots the sector gear matching with the same and thus the pivot member with the solar module (solar modules) fixed thereto.

Preferably, the sector gear covers an arc of about 120°, i.e. a third of a circle. By this, the desired pivoting of the pivot member for at least 90° can be obtained without having an upward protrusion of the sector gear beyond the members and without making impossible the arrangement of solar modules in this range.

According to a further development of the invention the pivot member with the sector gear is supported between two members fixedly connected to the rotary plate in a manner adapted to be pivoted upwardly. In this manner, a support of the pivot member with sector gear on both sides and thus a sturdy arrangement of the same is achieved. Practically, the motor, the reducing transmission and the transmission output shaft are supported at two members fixedly connected to the rotary plate which have between them the toothing of the transmission output shaft. By this, a sturdy design of the pivot drive is achieved, either.

For example, the member fixedly connected to the rotary plate and the pivot member can be formed as plate-like or rod-like members. The transverse extension of these members does not have any restrictions. Normally, the pivot frame extends beyond the rotary plate in lateral direction. According to a preferred embodiment the members are formed as rods, i.e. the pivot frame includes at least one rod fixedly connected to the rotary plate and at least one

pivot rod. According to a special embodiment the means includes four rods fixedly connected to the rotary plate of which the two outer ones are pivotally connected to a respective pivot rod and the two inner ones are pivotally connected to the pivot rod having the sector gear. Especially, two solar panels are fastened to the pivot rods and realize the connection between the driven pivot rod (the pivot rod provided with the sector gear) and the two other pivot rods.

Accordingly, the pivot frame, the pivot drive and the rotary plate form a unit rotationally supported on the base. Preferably, the rotary plate is rotatably supported on the base by means of balls disposed in an annular groove.

Preferably, the base consists of a bottom plate, a housing arranged thereupon and a fixed plate arranged thereupon for the support of the rotary plate. The annular groove is disposed in the fixed plate with one half and in the rotary plate with the other half. For example, the bottom plate can be connected by screwing, bonding etc. to the roof of a vehicle (mobile home, caravan). Practically, in the housing arranged on the bottom plate the rotary drive is housed which has a motor (electrical motor), a reducing transmission and a drive screw which is in engagement with a drive gear for the rotary plate. The drive gear is connected to a hollow hub which extends through the fixed plate and is connected to the rotary plate.

Suitable limit switches limiting the angle of rotation or the pivot angle are provided for the rotary drive and for the pivot drive.

Preferably, the optosensor is disposed at the solar module (solar panel). Furthermore, the pivot frame preferably carries two solar panels of which the upper one in the pivot position carries the optosensor. The optosensor and the limit switches for the rotary drive and pivot drive supply corresponding signals to a control unit (CPU) which controls the two motors for the pivot drive and rotary drive as well as is in functional connection with an operation panel with display which enables at least a manual switching-on and switching-off of the means and has, for example, a display with luminescence diodes which indicates the correct position of the means relative to the position of the sun.

The optosensor enables an especially exact detection of the position of the sun with a simple and compact construction. Preferably, it comprises the following components:

a base,

a separation means arranged on the base and separating the space above the base in a plurality of upwardly and laterally open compartments,

at least one light receiving means in each compartment which converts light into electrical current, and

electrical lines connected to the light receiving means and leading to a control/evaluation/display unit.

This design is based on the basic idea to provide with the separation means disposed on the base a means which throws a shadow in response to the position of the sun which covers one compartment or a plurality of compartments and thus the at least one light receiving means disposed in each compartment. Accordingly, dependent on the position of the sun the separation means can generate no shadow at all if the sun is positioned exactly vertically above the sensor and thus above the separation means or if, moreover, equal light conditions are present, as for instance in the night, with diffuse light etc., or the separation means can throw a shadow if its longitudinal axis forms an angle with the axis corresponding to the position of the sun. In this case, one compartment or a plurality of compartments and thus the corresponding light receiving means of the associated compartments are covered by the shadow generated by the separation means and thus do not generate electrical signals while the other compartments and associated light receiving means are free of shadow and generate electrical signals.

The electrical signals are supplied to a control unit which, in response to the received signals, operates the rotary drive and/or pivot drive which guide the solar module relative to the position of the sun, i.e. bring it into an optiumum position with respect to the sun, in which the sunrays impinge approximately vertically onto the surface of the solar module (surface of the solar panel).

Of course, the corresponding electrical signals are evaluated in a suitable manner before they fulfill their control functions.

If, for instance, the sensor and thus the separation means is aligned in such a manner that the axes of the sensor and of the separation means extend exactly parallel with respect to the sunrays at the highest position of the sun (noon), in this case all the light receiving means are in operation with a corresponding sun radiation and show the optimum position of the sun. Accordingly, a movement of a corresponding solar module is not necessary. If the angle of the sun radiation relative to the axis of the sensor changes now the separation means throws shadow onto one or several compartments so that one or several light receiving means are set out of operation which, as cited above, is indicated or results in a follow-up of the corresponding solar module until the optimum position is achieved again.

Preferably, the separation means divides the space above the base in four compartments. It forms a so-called "shadow cross" with which especially good results are obtained with regard to the operability of the sensor.

Pratically, a light receiving means is arranged in each compartment. This arrangement is sufficient in order to provide a sufficiently exact indication and control.

Preferably, a photodiode is used as light receiving means.

For the practice an embodiment has shown to be especially suited according to which the sensor has an approximately square base in horizontal cross-section and a separation means with walls arranged along the diagonals of the base. Accordingly, the separation means forms a "shadow cross" approximately corresponding to a St. Andrews cross in horizontal cross-section. Four triangular compartments are formed in which a respective photodiode is disposed with a suitable distance from the walls of the shadow cross. The photo diodes are fixed at the base wherein the corresponding electrical lines are combined within the base and extend outwardly of the base through an electrical cable. The cable is in connection with a suitable control/evaluation/display unit.

Practically, the sensor is provided at the solar module itself which is rotatably and pivotally arranged, i.e. it is co-moved into the optimum position of the solar module relative to the sun. Accordingly, the position of the sensor always exactly corresponds to the position of the solar module.

It can be generally stated: If all the light receiving means are illuminated with the same intensity (with sun radiation, diffused light, during the night) the associated control unit does not generate commands for the follow-up of the solar module. Such control commands are generated only if brightness differences occur between the several compartments (light receiving means). If such a difference occurs, preferably both drive means, i.e. the rotary drive and the pivot drive, are controlled (in a zigzag course) in

order to obtain a vertical position of the sun. Preferably, such a control unit is provided with a means for the suppression of oscillations in order to avoid a permanent movement of the drive means fore and back.

In the following the invention is described by means of an example in connection with the drawings in detail. Of the drawings

Figure 1 shows a vertical section through an automatically operating sun position follow-up means for solar modules;

Figure 2 shows a top view on the housing of the means of figure 1 with removed cover;

Figure 3 shows a top view of the means of figures 1 and 2;

Figure 4 shows a detailed view of a part of the pivot drive;

Figure 5 shows a schematical side view of an optosensor for the detection of the position of the sun;

Figure 6 shows a top view of the sensor of figure 5; and

Figure 7 shows a block circuit diagram of a sun

position follow-up means in which the sensor of figures 5 and 6 is used.

The sun position follow-up means for solar modules shown in figure 1 has a base consisting of a bottom plate 1, a housing 2 and a plate 3 disposed on the housing. A rotary plate 4 is rotatably supported on the base and carries a pivot frame 31 at which two solar panels 13 are fastened. These solar panels 13 convert sunlight into electrical current which, for instance, can serve for the supply of a vehicle on the roof of which the means is arranged.

For the installation of the means the bottom plate 1 is bonded or screwed to the roof of the vehicle. Dependent on signals generated by an optosensor 14 which is disposed at the upper solar panel 13 in the figure a rotary drive for rotating the rotary plate 4 and a pivot drive for upwardly and downwardly pivoting the pivot frame 31 are operated in order to adjust an optimum condition of the solar panels 13 relative to the sun (vertical impingement of the sunrays onto the panel plane).

The rotary drive for the rotation of the rotary plate 4 is disposed in the housing 2 arranged on the bottom plate 1. The rotary drive comprises an electrical motor 16, a reducing transmission 15 and a drive screw 9 which are arranged along an axis. The screw 9 is in engagement with a drive gear 8 which is fixedly connected to a hollow hub 7. The hollow hub extends upwardly through the fixedly installed plate 3 and is fixedly connected to the rotary plate 4. Accordingly, a rotation of the drive gear 8

generated by the drive screw 9 causes a rotation of the rotary plate 4. The rotary plate 4 is supported on the fixed plate 3 by means of balls 5 which are housed in an annular groove 6 which extends in both plates 3, 4 with a half.

The rotation of the drive gear 8 is limited by limit switches 18 which are contacted by a lever 17 which is guided through a mandrel in a screw groove disposed at the lower side of the drive gear 8. Accordingly, the drive gear 8 can carry out a rotation for 370° from abutment to abutment.

Furthermore, a box 10 is arranged within the housing 2 and houses a control unit 10 controlling the rotary drive and the pivot drive and to which corresponding signals by the limit switches of the rotary drive and the pivot drive as well as by the optosensor are supplied. Furthermore, the control unit 10 is in connection with an operation panel with display. The corresponding electrical lines herefor are not shown.

The pivot drive for upwardly and downwardly pivoting the pivot frame 31 is only schematically shown in figure 1 with 30. A more exact description of the pivot drive follows in connection with figures 3 and 4.

If a signal of the optosensor 14 is supplied through the control unit 10 which makes necessary a follow-up of the means by a rotary movement of the rotary plate 4, the motor 16 is controlled by the control unit 10. The output shaft

of the motor is rotated by this. A corresponding gear reduction is carried out by the transmission 15 so that the drive screw 9 has a substantially lower speed. The drive screw 9 drives the drive gear 8 in the selected direction. The rotation of the same results in a rotation of the rotary plate 4 in a manner determined by the control of the control unit or by the limit switches 18. The rotary plate 4 is rotated fore and back as long as it takes in the optimum rotary position for the position of the sun.

Figure 3 shows a top view of the rotary plate 4 on which the pivot frame 31 is fastened. The two solar panels 13 which are fixed at the pivot frame are only shown with dashed lines.

The pivot frame has two outer pivot rods 13 which are pivotally connected to a rod 11 fixedly connected to the rotary plate 4, as shown at 32. Furthermore, the pivot frame has a third approximately centrally arranged pivot rod 20 which is connected to the pivot drive and is thus pivoted. Its pivot movement is transferred through the solar panels 13 onto the two outer pivot rods 13. The central pivot rod 20 is pivotally connected to two inner rods 19 fixedly connected to the rotary plate 4.

Accordingly, on the whole seven rods are provided, namely three pivot rods and four fixedly installed rods. The two solar panels 13 are fastened at the three pivot rods 13 and 20.

Furthermore, the central pivot rod 20 is connected to a sector gear 25 which approximately corresponds to a third of a circle. This sector gear 25 and also the further parts of the pivot drive do not protrude beyond the upper sides of the pivot rods so that the solar panels cover the pivot drive and can extend along the whole length of the pivot rods. By this, in the collapsed condition of the pivot frame no parts protrude upwardly beyond the rod, and solar panels with an area as large as possible can be installed.

As shown in the detailed view of figure 4 the sector gear 25 is in engagement with the toothing of a transmission output shaft 26 of the pivot drive. By rotation of the shaft 26 the rod 20 is pivoted up and down whereby the solar panels are brought into the optimum position relative to the sun. The transmission output shaft 26 extends out of a reducing transmission 22 which is connected to a drive motor (electrical motor) 24 through another reducing transmission 23. The motor 24, the two reducing transmissions 23 and 22 and the transmission output shaft 26 are arranged along an axis. The whole drive means is flanged to the stationary rod 19, as shown at 21. The transmission output shaft is supported at the two stationary rods 19 by means of suitable bearing blocks (not shown).

If the pivot motor 24 is controlled by the control unit 10 its output shaft is rotated. A gear reduction of about 1:180 is obtained by the two reducing transmissions 23 and 22 which results in a reduced rotary movement of the toothed transmission output shaft 26. The same is in

engagement with the sector gear 25 and brings the pivot rod 20 and thus the solar panels 13 in the desired pivot position in this manner. Pivoting back is carried out vice versa. Suitable limit switches are also provided for limiting the pivot movement of the pivot frame.

Accordingly, an automatically operating sun position follow-up means for solar modules is described according to the invention which is largely maintenance-free on account of its mechanical drive and which has a very compact construction. Accordingly, solar panels with a large surface can be arranged, and the means does only generate a small wind resistance. A low construction height is obtained. The means is formed in an especially sturdy manner.

The optosensor shown in figures 5 and 6 has a base 100 which is only schematically shown as a corresponding pedestal. Its base is designed hollow in order to take-up corresponding wirings. On its lower side it has a cable outlet. According to this embodiment the base is approximately square in horizontal cross-section.

A separation means 200 is disposed on the base 100. In a horizontal cross-section the separation means has the shape of a St. Andrews cross. The separation means 200 forms four compartments 160 which are triangular in horizontal cross-section and which are upwardly and laterally open. Accordingly, sunlight can enter these compartments from above and from the side. The two other sides of the triangle which correspond to the diagonals of the base are

occupied by the walls 600 of the separation means 200 and thus shield the respective compartment with regard to sunligt.

A light receiving means 300 formed as photodiode is disposed in every compartment in a suitable distance from the separation means 200. Upon radiation with sunlight the photodiode 300 generates electrical signals which are supplied to an appropriate control unit through electrical conductors 400 which are combined in an electrical cable 500.

The separation means 200 has a suitable height in order to enable a shadow throw of the separation means 200 onto one compartment or a plurality of compartments and thus onto the ligth receiving means 300 disposed there upon an inclined position of the sun relative to the vertical axis of the sensor. The exact height can be determined empirically.

Figure 7 shows the sensor of figures 5 and 6 as part of a sun position follow-up means. The sensor is indicated at 800 and is disposed at the rotatably and pivotally movable solar module. The corresponding signals of the sensor 800 are supplied to a control unit 700 (central processing unit, CPU) which also receives signals from the switches 900, 1000 of the rotary drive and pivot drive, evaluates the received signals and outputs corresponding control command signals to the rotary drive 110 as well as the pivot drive 120. Furthermore, the control unit 700 supplies

signals to an indicating/operating unit 130. This unit has a display 140 and an on/off-switch 150.

The whole means operates as follows:

The user switches on the means with the switch 150. The sensor 800 detects the position of the sun and applies corresponding signals to the control unit 700. These signals are shown in the display 140. Furthermore, by this, if necessary, corresponding command signals are generated which are supplied to the rotary drive 110 and/or the pivot drive 120 which cause a follow-up of the solar module. The provided limit switches 900, 1000 terminate the corresponding movements of the solar module.